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Some features of the decay of Au^{198} to Hg^{198}

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With 3 figures in the text

ABSTRACT

Hg^{198} is found to emit gamma rays of energies 0.67575 Mev and 1.0875 Mev in decaying from its second excited state. A splitting of this state, which has recently been reported elsewhere, is not observed. The β-branching to a state at 1.000 MeV, observed in the decay of Tl^{198m}, is shown to be weaker than theoretically expected. The results are discussed.

Introduction

A few nucleons added to a closed shell, may be treated in theory as moving in the central potential of this stable core. As the interaction between these extra particles must be taken into account, the computational difficulties increase rapidly with the number of added nucleons. However, with a more complicated system, it is fortunately possible to separate the equation of motion into one for the independent particles and one for the nucleon cloud as a whole. For even-even nuclei, the energy for excitation of a single particle is found to be higher than the energy of the surface waves; therefore it is sufficient to deal with collective phenomena in order to describe the lower excited states of these nuclei. For nuclei far away from closed shells the equilibrium shape is ellipsoidal, and the collective motion produces the well known rotational bands. Nearer to the closed shells there is a region where the shape is almost spherical and the rotational energies accordingly very high. It was first suggested by Scharff, Goldhaber, and Weneser (1) that the low lying levels exhibited by nuclei in this region may be described in terms of collective vibrations of an incompressible spherical system. The behavior of the system is that there exists a level sequence $n \times h\nu$ $(n = 0,1,2,\ldots)$, where the selection rule for transitions is $\Delta n = 1$. In the zero coupling case the character of the three lowest states would be $0+$, $2+$ and $0+, 2+, 4+$ (degenerated). Under this idealization the second excited state would be observed to have a distribution of different spins, the percentages depending on the probabilities of the feeding β- and γ-decay. With coupling, and with possible unharmonic contributions taken into acount, the degeneration will be destroyed. However, no certain experimental evidence for the resulting level triplet has yet been reported. The second excited states of most nuclei in these regions are experimentally found to be $2+$, even if there are no obvious reasons for the non-population of, say, a neighbouring $0+$ level.

${}_{80}Hg^{198}$ is known to show the level sequence $0+$, $2+$, $2+$ (Fig. 1). Hammermesh and Smither (2) have recently reported a definite splitting of its second excited level.

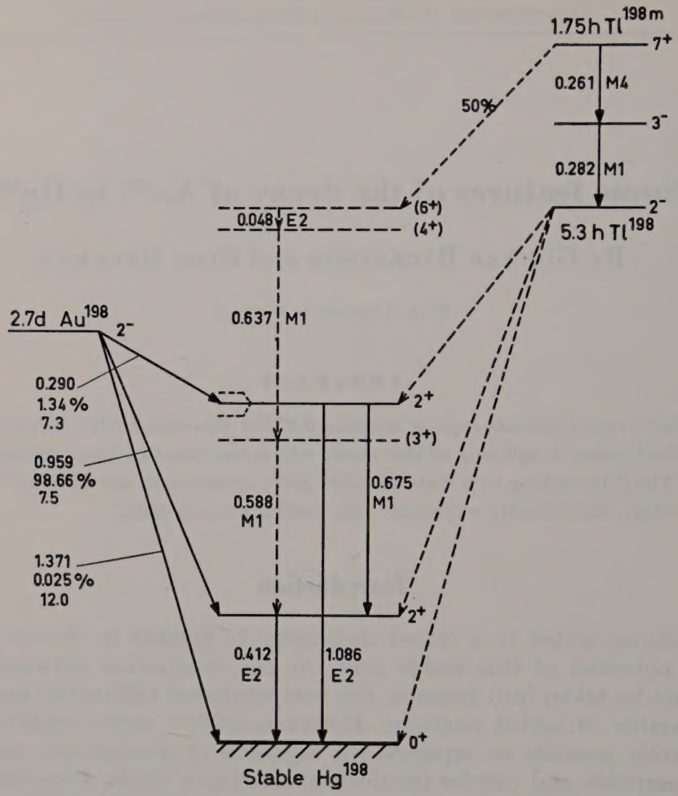

Fig. 1. The level scheme of Hg,^{198} as suggested by Andersson and Bergström. The two closely lying levels indicated by the data of Hammermesh and Smither are shown in the left part.

The method they used was to measure, with a large, bent crystal spectrometer, the γ-spectrum from a gold sample, fixed in the interior of a reactor. The spectrum observed will then contain the γ-transitions in Au^{198}, following the neutron capture, as well as gamma rays in Hg^{198}, formed by the decay of Au^{198}. The intensities of the first class of lines will be proportional to the neutron flux, whereas the second group will be observed to rise. After the reactor is shut down, only the γ-spectrum belonging to the decay is observed. The authors report lines of energies 0.6711 Mev and 0.6789 Mev and two unresolved cross-over transitions at 1.090 Mev, all belonging to Hg^{198}.

Andersson and Bergström (3) have recently revised the decay of the metastable state Tl^{198m}. On the basis of their new findings and earlier data they suggested the decay mode indicated in Fig. 1. The authors consider the level scheme tentative. However, it seems convincing that either the 0.588 Mev or the 0.637 Mev line leads to the first excited state. This introduces a second new level not far from the previously reported second excited state.

As it might be possible that for intensity or energy reasons, evidence for these new levels might have been overlooked in earlier investigations of the decay of Au^{198}, a careful search for the corresponding lines is indicated.

Experiment and results

A gold rod of 1 mm diameter was irradiated for 3 days in a slow neutron flux of 10^{12}/cm^2 s. The resulting source strength was about 500 mC. As there are no intense high energy gamma lines, it was rather easy to observe photo-electrons ejected from a Uranium foil of thickness 4.4 mg/cm^2. The energy selection was done by a 50 cm radius double focusing spectrometer with a field measuring device (4). The resulting relative line half-width was 0.4–0.5 %.

After careful demagnetization the run was taken by recording first the Ba^{137} 0.662 Mev standard (5), then the supposed two doublets in Hg^{198}, and last, still increasing the current, a calibration line (5) in Ni^{60}. The measurement on the Ba and the lower Hg line was repeated. These two transitions are so close together, that a satisfactory energy computation can be made simply by using electron momenta defined by the center of each line. For the gamma line of 1.090 Mev the evaluation is more involved. Because of electron straggling and energy dependent differential photo cross-section, the line center is not a good measure of the electron momentum. Taking instead high energy edges the calibration constant differs by 3 parts in 10^4 when comparing the Ba and Ni lines. In order to obtain a calibration pertinent to the upper Hg line, an interpolation was made.

Instead of a doublet of 0.6711 Mev and 0.6789 Mev with the reported intensity ratio 3:1, we find a single line of energy

$$E_{\gamma_1} = 0.67575 \pm 0.00025 \text{ Mev}$$

and similarly no doublet at 1.090 Mev but

$$E_{\gamma_2} = 1.08747 \pm 0.00035 \text{ Mev}.$$

The difference is accurately equal to the well-known standard line of 0.41182 Mev and consequently the transitions observed define only one single level at 1.0875 Mev.

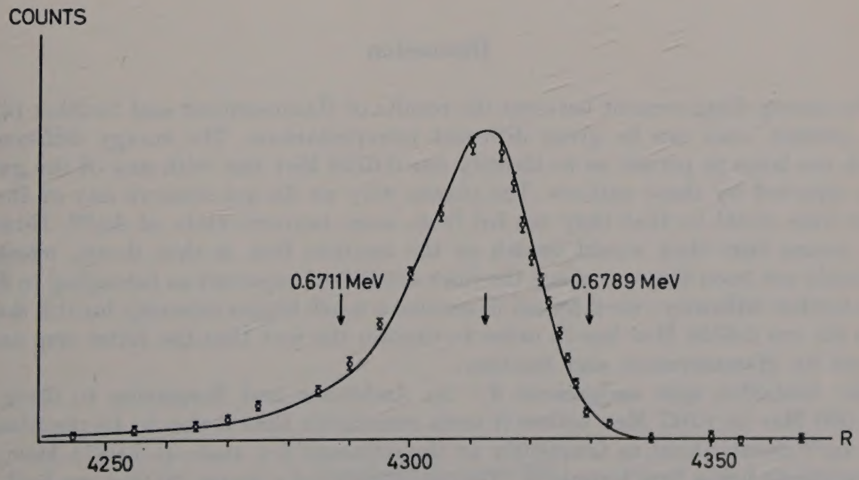

Fig. 2. The photoline of the 0.676 Mev gamma ray (points), compared to the normalized Ba^{137} standard line (continuous curve). The positions of the previously reported lines are indicated by arrows.

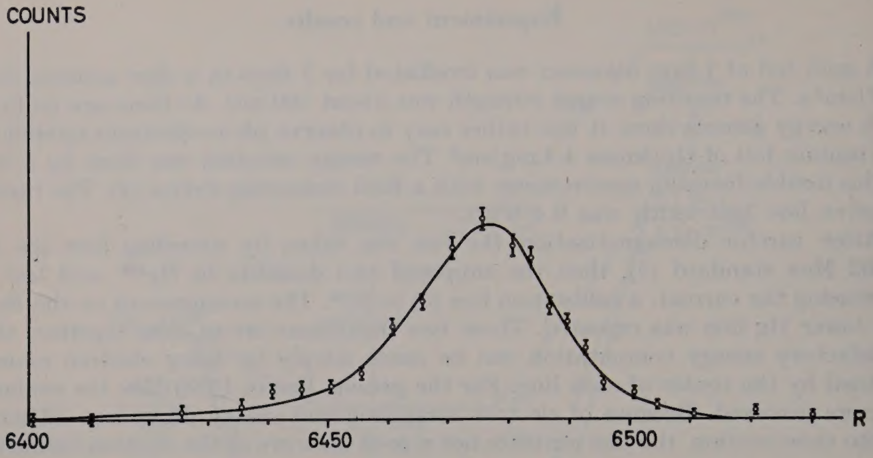

Fig. 3. Analysis of the shape of the Uranium *K* line (points) of the 1.087 Mev transition. The continuous curve shows the shape of a standard line.

From Fig. 2, where the line shape is further analyzed, it is obvious that if there are lines in this decay of the energies reported by Hammermesh and Smither, they must be very weak.

The above result has been checked by the method of internal conversion, using a thin electroplated source. The results are not equally accurate, but definitely decide in favour of the intermediate energy found in external conversion.

The transitions known from the decay of Tl^{198} were carefully looked for, and an upper limit $\frac{1}{20}$ could be given for their intensity in comparison with γ_1.

Discussion

The strong disagreement between the results of Hammermesh and Smither (2) and the present ones can be given different interpretations. The energy difference is much too large to permit us to identify our 0.6758 Mev line with any of the gamma rays reported by these authors. The reason why we do not observe any of the two other lines could be that they are fed from some isomeric state of Au^{198}. However, this means that they would vanish as the neutron flux is shut down, which has probably not been the case, since the lines are indeed reported as belonging to Hg^{198}. As a further difficulty, one is forced to assume a much higher intensity for this doublet than for our 0.6758 Mev line in order to explain the fact that the latter was not observed by Hammermesh and Smither.

The tentative spin assignment 3+ by Andersson and Bergström to their level at 1.000 Mev or 1.047 Mev makes it seem reasonable that it should be populated in the Au^{198} decay about as frequently as the adjacent 2+ state at 1.0875 Mev, both β-transitions being first forbidden. The retardation of a factor 20 that we find, does of course not exclude a 3+ assignment, but a spin-parity of 4−, or possibly 4+, seems now more probable.

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